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Studies on the influence of some fungi on Collembola and Acari

By A. Z. Farahat

With 2 figures in the text

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Contents

1. Introduction 258
2. Acknowledgements 259
3. Materials and Techniques 259
4. Experiments 261
5. Results 262
6. Discussion 266
7. Summary (Zusammenfassung) 267
8. References 267

1. Introduction

The study of the relationship between soil microfauna (Collembola and Acari) and soil fungi has drawn the attention of many zoologists during the last fifty years. Fungi have been considered as a favourite diet for many species of micro-arthropods. Macnamara (1924), Handschin (1926), Agrell (1941), Forsslund (1938, 1943), Weis-Fogh (1948), Kühnelt (1950), Schaller (1950), Riha (1951), Schuster (1956), Hartenstein (1962) and Woodring (1963) reported that many Collembola and Acari feed on fungal hyphae and spores. However, Schaller (1950) and Kühnelt (1961) believed that most of the fungal spores consumed by Collembola such as *Hypogastrura* species are not digested and leave the gut in a viable condition.

Investigating the influence of soil fungi on the distribution of the litter fauna, Forsslund (1943), Fenton (1947), Weis-Fogh (1948) and Kühnelt (1950) recorded great differences between the fauna of normal litter and that of litter rich in fungi.

Recently, Kühnelt (1963) conducted a valuable investigation on the influences of mycelia of *Clitocybe infundibuliformis* on the litter fauna. He compared the fauna of the infected and uninfected leaves both quantitatively and qualitatively. By determining the pH value, the water, tannin and cellulose contents of infected and uninfected leaves, it was found that oribatids and gamasides are not affected by the growth of the mycelium.

Furthermore, he concluded that litter rich in mycelia, is poor both in species and individuals of Collembola. This was attributed to the shifting of the pH of the infected leaves towards acidity as a result of the mycelial growth. However, some Collembola, for example *Xenylla brevicauda*, are more numerous in acid litter which is rich in fungi.

The present work is an attempt to find out the main factors which control the relationship between soil fungi and Collembola and Acari.

2. Acknowledgement

I wish to express my deep gratitude to Professor W. Kühnelt, Director of the Second Department of Zoology, University of Vienna, for his valuable advice and continous encouragement throughout the whole work. I am also grateful to the members of the staff of this Department: Dr. H. Nopp for his valuable advice, Dr. E. Pipel and Mr. K. Mais for helping in the identification of oribatids and Collembola respectively. My thanks are also due to Dr. J. Thurner (Universitäts-Hautklinik, Wien) for the identification of the fungi.

3. Materials and techniques

This investigation was performed on Collembola and Acari of two types of soil. The samples of the first type were taken from an Isopod culture which was kept in the laboratory in well-covered glass containers for five years before the start of the experiments. This type will be referred to as soil I. It contained *Entomobrya lanuginosa*, *Rhizoglyphus echinopus*, *Oppia splendens* and one gamasid species belonging to family Laelaptidae. The samples of the second type of soil were collected from Vienna woods (Neuwaldegg and Hütteldorf) and were kept in laboratory in well-covered glass containers for four months at least before the start of the experiments. This type will be referred to as soil II. It contained *Folsomia multiseta*, *Oppia ornata*, *Hypochthonius rufulus*, *Achipteria coleoptrata* and one gamasid species belonging to family Laelaptidae.

The mycelia of *Trichoderma viride* and *Rhizopus nigricans* were chosen for this study because of the ease with which they could be cultivated in soil samples kept in the laboratory.

The animals were separated from soil samples using Tullgren's modification of the Berlese apparatus. The soil samples were carefully spread out on the wire mesh nets of the funnels. The upper opening of the funnel was covered by a piece of muslin to prevent certain animals from escaping. The animals were collected in a glass vial containing a mixure of glycerine and 70% ethanol (1 : 10). Animals used for breeding experiments were collected in a glass vial containing 3 cc of distilled water.

The collected animals were sorted out under a binocular stereomicroscope using a fine brush. For microscopic examination, the animals were transferred to a watch glass containing 60% lactic acid which serves as a clearing medium. Temporary preparation was done by transferring the animal to a cavity slide containing a drop of lactic acid. The preparation was gently warmed until the specimen became stretched and cleared, the animal orientated and the coverslip applied. The orientation of the animal could be easily changed, if needed, by moving the coverslip carefully.

Gisin's (1960) key for the identification of European Collembola and Baker and Wharton's (1959) key for the identification of mites were used.

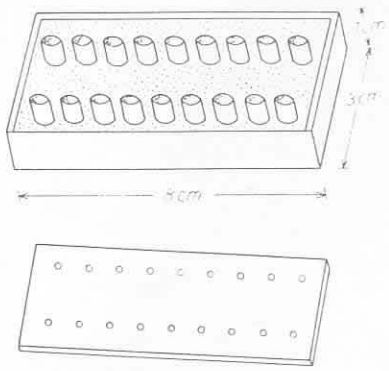

Fig. 1. Gypsum cage.

For breeding experiments gypsum cages or plastic trays were used. The gypsum cage is simply a gypsum plate with two small rounded grooves as illustrated in Figure 1. Each groove contained a few fungal hyphae growing on a small piece of bread. The top of the cage was covered with a glass slide which could be easily moved, thus permitting direct observation and air exchange. The cages were kept in a large glass container in which moistened sand was placed to keep the environment suitably humid. The relative humidity was about 100%. The plastic tray (different sizes were

used according to the size of the animals) consists of a plate with 18 grooves arranged in two rows as illustrated in Figure 2. A few fungal hyphae were grown on a moistened piece of filter paper in each of these grooves. The moistened filter paper was changed every week. The plastic tray was covered with a special slide (made of paraglass) which has a number of holes arranged so that each groove of the plastic tray is in direct contact with the external surroundings. Each tray was placed in a Petri dish which contained moistened filter paper. (R. H. was near 100 %.)

The fungal extract offered as a food for captured animals was prepared by crushing the fungal hyphae in a small mortar and transferring the extract to the grooves of the plastic trays by means of micropipette.

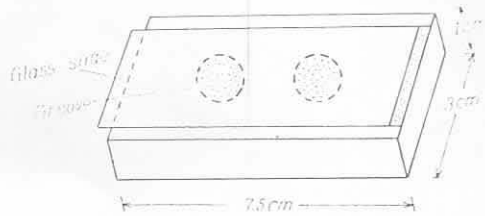

Fig. 2. Plastic tray and its slide.

The gut contents of the animals were studied by cutting the gut (in a mixture of 96 % ethanol, glycerol and water in equal proportions), opening it and mounting its contents in a cavity slide. In the case of very small species, the entire contents of the body were mounted due to the difficulty of separating the gut from the internal structures.

The droppings (faeces) of the animals were collected by transferring the animals from the breeding compartments to a clean plastic tray where they were kept until they defaecated. The droppings were transferred by a fine brush to a cavity slide and were mounted in the same way as the gut contents.

4. Experiments

The following experiments were designed to assess the factors that control the relationship between fungi and both Acari and Collembola. These experiments were carried out in the laboratory at room temperature, 20 °C (± 2 °C).

1. Effect of cultivated fungi on the soil microfauna.

The fungi were cultivated in soil I and II. Soil I was divided into two halves. Each half was kept in a separate well-covered glass container and the height of the soil in the two containers was 3 cm. The fungi were cultivated in one half on 9. 2. 1965, while the other half was left untreated serving as a control. Three equal soil samples from each half were transferred to the Berlese funnels on 14. 4. 1965, 18. 5. and 19. 6. 1965. The fauna was identified and the results are shown in Table 1.

Table 1 Effect of cultivated fungi on Collembola and Acari of soil I.

Date of sampling			14. 4. 1965		18. 5. 1965		14. 6. 1965	
Name		Soil:	without Fungi	with Fungi	without Fungi	with Fungi	without Fungi	with Fungi
Collembola	*Entomobrya lanuginosa*	Adults	4	171	3	170	5	163
		Nymphs	8	22	—	9	1	5
Gamasidae	Laelaptidae (Big species)	Adults	4	42	3	55	1	48
		Nymphs	9	71	4	40	12	32
Acaridiae	*Rhizoglyphus echinopus*	Adults	2	106	4	120	2	78
		Nymphs	115	1385	70	770	76	350
Oribatei	*Oppia splendens*		16		13	1	12	2

Table 2 Effect of cultivated fungi on Collembola and Acari of soil II.

	Date of Sampling	25. 3. 1965		20. 4. 1965			18. 5. 1965			14. 6. 1965		
Name	Soil:	without Fungi 3 cm.	with Fungi 3 cm.	without Fungi 3 cm.	with Fungi 3 cm.	with Fungi 1 cm.	without Fungi 3 cm.	with Fungi 3 cm.	with Fungi 1 cm.	without Fungi 3 cm.	with Fungi 3 cm.	with Fungi 1 cm.
Collembola	*Isotomiella minor*	26	6	9	4		8	6	5	3		
Mesostigmata	Gamasina (Laelaptidae) Adults	2	11	2	6	3	2	3	28	2	35	28
	Nymphs	3	72	7	160	123	5	150	173	4	201	264
	Prozercon fimbriatus	15	8	7	1	3	10	6	3	8	5	3
Oribatei	*Oppia ornata*	10	7	22	10	7	18	6	2	18	—	1
	Achipteria coleoptrata	2	4	—	2	2	1	4	4	1	2	4
	Hypochthonius rufulus	1	4	1	3	4	2	1	6	1	3	4

Soil II was divided into three equal portions, each portion being kept in a separate glass container. The height of the soil of the first and second portions was 3 cm, while that of the third portion was 1 cm. Fungi were cultivated in the second and third portions on 1. 3. 1965, while the first portion was left untreated as a control. On 25. 3., 20. 4., 18. 5. and 14. 6. 1965 three equal samples were treated as in soil I. The results of the experiment are shown in Table 2.

2. Breeding of isolated animals on fungi.

Individuals of different species were kept on growing fungi in gypsum cages as previously described. The animals were reared in these cages from the beginning of March 1965 until the end of July 1965. Observations on feeding habits, locomotory activity, reproduction and defaecation were recorded daily and these observations are presented in Table 3.

To test whether the animals in the previous experiment were feeding on the fungi or on the bread, plastic trays instead of gypsum cages were used as rearing compartments. In this case, the fungal hyphae were kept on a moistened piece of filter paper (Relative humidity was near 100%). Different species were reared in these trays from the beginning of April 1965 until the end of July 1965. Daily observations on their different activities were also noted and these are shown in Table 3[1]). Some experiments were designed to find out whether or not nymphs of certain species can feed on and/or tolerate the fungus: the results are included in the same Table. The effect of fungal extract on the adult animals was also tested. The animals were kept in the grooves of the plastic tray with the fungal extract. In addition, the effect of depriving the animals of food was investigated. The animals were kept in plastic trays with a few drops of distilled water. The water was renewed every three days to prevent the development of Protozoa which are favourite food for many species. Another set of experiments was performed to determine the length of time, during which each species can withstand starvation. The animals were transferred to the grooves of plastic trays in which small pieces of moistened filter paper or a few fibres of moistened glass wool were placed. The results of these experiments are also included in Table 3.

3. Studying the gut contents.

The separated animals were reared in gypsum cages containing growing fungi. A week or two later, the animals were sacrificed and their gut contents were mounted and examined.

4. Studying the droppings (faeces).

The droppings of the animals reared on growing fungi in gypsum cages or in plastic trays were carefully collected and examined to determine whether or not they contained any fungal structures.

5. Results

The results are shown in Tables 1—4 and the following is an interpretation of these results in a taxonomic sequence.

A. Collembola

Various species representing the different families of Collembola were studied.

(1) Family Entomobryidae: *Entomobrya lanuginosa* NICOLET

The individuals of this species showed an increase in soil I which contained growing fungi (Table 1). Both adults and nymphs were reared successfully in gypsum cages or

1) Table 3 s. appendix.

plastic trays containing growing fungi or their extracts. This species had two generations during the experimental period in the gypsum cages. Feeding, defaecation, moulting, reproduction and locomotory activity over this period appeared to be normal. This species was able to live for two weeks without food but did not defaecate. Observations on the feeding habits and examinations of the gut contents revealed that this species feeds on both hyphae and spores. Small pieces of fungal structures were detected in the faeces.

It is clear, therefore, that fungus is a suitable food for this species and this may account for its abundance in soils rich in fungi.

(2) Family Poduridae: *Hypogastrura granulata* STACH

The animals were successfully kept in plastic trays containing growing fungi. During the period of the experiment, they were active, moulted and defaecated. They lived for a long period when kept with water but, they died after a few days when kept with fungal extract. After observing their feeding habits, it could be stated that they feed on both hyphae and spores. SCHALLER (1950) found Basidiomycetes spores in the gut of *Hypogastrura armata* and he believed that these spores are not digested and also their diameter increased in the hind gut of these animals due to swelling. KÜHNELT (1961) stated that „with regard to Collembola (*Hypogastrura* species), it should be noted that they do not live permanently and predominantly on fungal spores, but where spores are abundantly present, they feed on them for preference and undamaged spores leave the gut, for the most part, in a viable condition". This statement made for higher fungi (Basidiomycetes) does not apply at least to the two species of these fungi used in my experiments. Examination of the gut contents revealed that both hyphae and spores were found in the gut of this species. The spores and hyphae were digested in the gut and only a few of them went out without complete digestion.

These results indicate that the fungi are a favourite diet for *Hypogastrura* and may be regarded as one of the main factors responsible for its occurrence in soil rich in fungi.

(3) Family Isotomidae: *Isotomiella minor* SCHÄFFER, *Folsomia multiseta* STACH

The individuals of *Isotomiella* were successfully reared in both gypsum cages and plastic trays containing growing fungi. Various activities were apparently normal and the species produced a new generation during the period of the experiment. This species died after few days when kept with fungal extract but lived for a long period when kept with water. Feeding habits and gut content observations indicated that the species feed only on fungal spores.

Most individuals of this species died after few days when kept in plastic trays containing fresh mycelia (which had not yet developed spores) as shown in Table 4. However, the individuals which survived until the development of the spores lived for long periods feeding on these spores. This indicates that the presence of fungal spores is an essential for the existence of this species in containers with cultivated fungi.

The individuals of *Folsomia multiseta* decreased in number in soil II containing growing fungi as shown in Table 2. They died after few days when kept with growing fungi or their extracts. Observations on the feeding habits of this species showed that it does not feed on any fungal part and this is supported by gut content examinations. This may explain why this species decreased, in number in the containers with cultivated fungi.

(4) Family Sminthuridae: *Sminthurides pumilis* KRAUSBAUER, *Arrhoopalites cochlearifer* GISIN

The individuals of these two species did not exhibit any of the vital activities when kept with growing fungi or their extracts, and they died a few days later. Their guts were free from fungi and it is almost certain that the animals died due to starvation.

That these two species do not feed on fungi explains, at least in party, why they became rare in containers with cultivated fungi.

Table 4 Survival (expressed in days) of *Isotomiella minor* in plastic tray cultures containing fresh fungal mycelia.

Date / Number	June 1965 12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
8	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
13	+	5	+	+	+	3	+	+	+	+	+	+	+	+	+	+	+	+	+
5	+	2	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
6	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
3	+	+	+	Dead		.	.	.	.	.	.	.	.	.	.	.	.	.	.
4	+	3	+	Dead		.	.	.	.	.	.	.	.	.	.	.	.	.	.
6	+	+	4	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
5	+	+	3	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
8	+	+	3	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
5	+	+	3	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
1	+	+	+	Dead		.	.	.	.	.	.	.	.	.	.	.	.	.	.
6	+	+	Dead		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3	+	+	+	1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
3	+	+	2	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
11	+	+	1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
7	+	+	7	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
1	+	+	Dead		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
8	+	+	5	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
4	+	+	1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
2	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
1	+	+	Dead		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

B. Acari

Various species belonging to sub-order Mesostigmata (Parasitiformes) and to sub-order Cryptostigmata (Sarcoptiformes) were studied. Each species has its own characteristic affinity towards fungi, as will be shown below.

(1) Sub-order Mesostigmata

The following three groups of this sub-order were studied.

a) Gamasina: Two species belonging to family Laelaptidae were studied. The individuals of these two species increased in number in soils I and II which contained growing fungi (Table 1 and 2). Adults and nymphs of the two species were successfully kept in both gypsum cages and plastic trays containing growing fungi. They produced a new generation during the experimental period. After observing their feeding habits and examining their gut contents, it can be stated that they feed on both hyphae and spores, although spores are preferred. FORSSLUND (1943) noticed that places rich in fungi harboured roughly twice as many Gamasiformes as those poor in fungi. Moreover, he stated that certain species were restricted to soils rich in fungi.

Therefore, it is clear that fungi are consumed by these two species and its presence may influence their distribution.

b) Uropodina: Family Discourellidae, *Discopoma* sp.
Family Urodiaspidae
Family Uropodidae
Family Phaulodinychidae.

Four species belonging to the above mentioned families were studied. They were successfully reared in gypsum cages and plastic trays containing growing fungi or their extracts. The feeding habits of these species were not observed directly because the prosoma of the animal extends over the gnathosoma which is enclosed within a special cavity, the camerostome. The gut contained both hyphae and spores.

All the data indicate that these species feed on fungi and their extracts. So the presence of fungi in soils may have a great influence upon their occurrence.

c) Zerconina. Family Zerconidae. *Proscheon fimbriatus* Koch

The individuals of this species decreased in number in soil II containing growing fungi as shown in Table 2. They died after a few days when kept with growing fungi or their extracts. During this period they did not show any vital activity. They also died after the same period when kept either without food or with water only. Their gut contents were free from fungi.

It is almost certain that the animals died because they could not feed on fungi and this would explain — at least in part — why they are rare in soil rich in fungi.

(2) Sub-order Sarcoptiformes

Various species belonging to the two divisions of this sub-order were studied.

(2.1.) Acaridae: Family Acaridiae (Tyroglyphidae): *Rhyzoglyphus echinopus* Fumouze and Robin.

The individuals of this species increased in number in soil I containing growing fungi (Table 1). Both adults and nymphs were successfully reared in gypsum cages and plastic trays containing growing fungi or their extracts. Feeding, locomotory activity, defaecation, moulting and reproduction appeared to be normal. The adult female laid large numbers of eggs, from 18 to 25. The eggs hatched few days later. Both adults and nymphs fed on hyphae and spores with great voracity and they produced great quantities of faeces. Their guts contained considerable amounts of spores and hyphae. Only a few pieces of hyphae and a small number of spores were found in their droppings, not completely digested. Woodring (1963) said that *Rhizoglyphus echinopus* can be easily cultured both on food contaminated with bacteria, yeast or fungi and on fungi alone, in the form of hyphiae or ground dried mushrooms. It is assumed, therefore, that the presence of the fungi in soil may play an important part in the distribution of this species.

(2.2.) Oribatei: Different families belonging to this group were studied.

a) Family Oppiidae: *Oppia splendens* Koch, *Oppia ornata* Oudemans and *Oppia nitens* Koch.

The first and second species decreased in number in soil I and II which contained cultivated fungi (Table 1 and 2). They died after few days when reared in gypsum cages or in plastic trays containing growing fungi or their extracts. They also died after the same period when kept either without food or with water only. They never defaecated during that period and their guts contained no fungi.

The results indicate that the two species do not feed on fungi and most probably death occurred due to starvation.

The individuals of the third species *Oppia nitens* are relatively larger than the preceding species. They were successfully reared in plastic trays containing growing fungi. The animals were very active during the period of the experiment. Their guts contained only the spores of fungi.

Van der Drift (1961) and Schuster (1956) found some fungal hyphae in the gut contents of *Oppia neerlandica* Oudemans and *Oppia subpectinata* Oudemans respectively. Hartenstein (1962) said that *Oppia nova* Oudem. can feed only on fungi. These data indicate that no general statement can be made for the genus *Oppia*.

b) Family Hypochthoniidae: *Hypochthonius rufulus* Koch.

This species increased in number in soil II containing growing fungi (Table 2). Adult animals were successfully reared in the gypsum cages and plastic trays containing growing fungi. They died after a short time when kept without food, with water or fungal extracts. The guts contained spores and hyphae. Hartenstein (1962) offered different kinds of food to this species and he found that it fed only on some species of fungi such as *Alternaria* species, *Cladosporium cladosporioides* and *Stemphylium* species. It refused the fungi named *Trichoderma koningi*. He considered *Hypochthonius rufulus* to be a strictly fungivorous oribatid. These results indicate that fungi are a suitable diet for this species.

c) Family Phthiracaridae *Rhysotritia ardua* KOCH, *Tropacarus pulcherrimus* BERLESE.

These two species lived for a long period when reared in the large gypsum cages containing growing fungi, but died after two weeks when kept in the small plastic trays containing fungi, their extracts, distilled water or no food. During these experimental periods, they kept their bodies contracted and their legs withdrawn. Occasionally, the animals stretched their bodies and moved slowly, apparently because the fungal hyphae hindered their movements. The guts contained no fungi. FORSSLUND (1938), VAN DER DRIFT (1951), RIHA (1951), MURPHY (1953) and HARTENSTEIN (1962) stated that all species belonging to the family Phthiracaridae are typical macrophyte feeders.

The present results indicate that the individuals of the two species do not feed on any fungal part. On the other hand, the animals lived for considerable periods in the gypsum cages, simply because they did feed on the bread used for the fungal cultivation.

d) Family Achipteridae *Achipteria coleoptrata* LINNAEUS.

This species increased in number in soil II which contained cultivated fungi (Table 2). The adult animals were successfully reared in the gypsum cages containing growing fungi and in the plastic trays containing fungal extracts. They did not thrive in plastic trays containing growing fungi because the hyphae hindered their movements since their bodies are provided with long pointed processes. In nature, the fungi do not grow as densely as in these experimental conditions. The guts contained hyphal parts but no spores. FORSSLUND (1938) found also fungal hyphae in the gut of another species, *Achipteria punctata* NICOLET.

The fungal hyphae seem to be a suitable diet for these species and may be responsible for their abundance in containers with cultivated fungi.

e) Family Liacaridae: *Liacarus tremellae* WILLMANN.

This species was reared successfully in plastic trays containing growing fungi. During the period of observation, the animals fed, defaecated and moved. Their guts contained hyphae and spores. SCHUSTER (1956) reported that this species does not depend upon any special type of food. KÜHNELT (1950) observed *Liacarus xylariae* SCHRANK feeding on fungi.

It is evident, therefore, that fungi are also a suitable diet for these species.

6. Discussion

Many ecological factors, such as water content of the soil, organic substances, root content, hydrogen ion concentration, structural and nutritive factors, have a great influence on the composition and distribution of soil microfauna. FRENZEL (1936) and AGRELL (1947) believed that the nature of the food had no influence on the occurrence of Collembola and Acari. They considered only the amount of food, not its nature to be the important factor. FORSSLUND (1943) and WEIS-FOGH (1948), on the other hand, have pointed out the importance of the nature of the diet. They correlated the differences in the nutritive conditions with the distribution of some species of Collembola and Acari in different habitats. KÜHNELT (1950) drew the attention to the importance of the nutritive factor in the distribution of soil micro-arthropods.

According to the results obtained in the present work, it is concluded that species which can feed on fungi, have a good chance to increase in number in soil rich in fungi while other species which do not feed may diminish. Also, the presence of spores is an important factor, since some species such as *Isotomiella minor* fed exclusively on spores under our experimental conditions, while others such as *Hypogastrura* and Gamasidae preferred feeding on spores. Considering the fact that fungal growth in nature is not as abundant as in the laboratory cultures, one may expect that there is a strong competition between the different species feeding on fungi. The species which feed only on spores have

a smaller chance of existence, since other species that feed on hyphae will consume them before spore-development.

With regard to the effect of hydrogen ion concentration of the soil on the distribution of Collembola and Acari, there are many different views. GISIN (1943) regarded the hydrogen ion concentration of the soil to be of great importance for the distribution of Collembola. WEIS-FOGH (1948), however, stated that small differences in the hydrogen ion concentration of different soils have no great significance. KÜHNELT (1963) found that the change in the hydrogen ion concentration of litter due to the growth of fungi has a great influence on Collembola but not on Acari.

Preliminary investigations of the hydrogen ion concentration of the soil with and without cultivated fungi indicate that there is a slight difference. Also, the hydrogen ion concentration of the fungal extracts was found to be nearly equal to that of the distilled water. Some Collembola: *Entomobrya lanuginosa* and some Acari: *Uropodina*, *Rhizoglyphus echinopus*, *Achipteria coleoptrata* behaved normally when kept with fungal extracts. Other species of Collembola and Acari died when kept with the extract, possibly due to the antibiotic effect of fungi or to starvation.

7. Summary

In the present work, the effect of cultivated fungi on Collembola and Acari has been investigated in the laboratory. Individuals of the different species were reared on growing fungi or on their extracts. Observations on their feeding habits, locomotory activity, reproduction and defaecation were recorded daily. The gut contents and the droppings were carefully examined. It was found that *Entomobrya lanuginosa*, *Hypogastrura granulata*, *Rhizoglyphus echinopus*, *Hypochthonius rufulus*, *Liacarus tremellae*, and two gamasid species belonging to family Laelaptidae can feed on both fungal hyphae and spores. Some species such as *Achipteria coleoptrata* can feed only on hyphae, while other species such as *Isotomiella minor* and *Oppia nitens* can feed only on spores under the described conditions. Many species such as *Folsomia multiseta*, *Sminthurides pumilis*, *Arrhopalites cochlearifer*, *Prozercon fimbriatus*, *Oppia splendens* and *O. ornata*, *Rhizotritia ardua* and *Tropacarus pulcherrimus* can not feed on any fungal structure. These results indicate that every species has its own characteristic affinity towards the fungi. The species which fed on fungi increased in number in containers with cultivated fungi, while others which did not feed decreased. The presence of fungal spores is an important factor, since some species feed only on them in my experiments. These species have smaller chance for existence when compared with other species which feed on both hyphae and spores or on hyphae alone.

The feeding habits of Collembola and Acari towards the two studied fungi can not be applied or generalized on different species of fungi, since some Collembola such as *Hypogastrura* sp. can not digest the spores of higher fungi (Basidiomycetes).

It is believed that the amount of food and its nature are important factors which control the relationship between soil fungi and Collembola and Acari.

7. Zusammenfassung

Es wurde das Verhalten verschiedener Collembolen und Milben gegenüber zwei Schimmelpilzen (*Trichoderma viride* und *Rhizopus nigricans*) untersucht. Hierzu wurden verschiedene Versuchsanordnungen gewählt. Die Myzelien und Kleinarthropoden wurden entweder in flachen Gipskäfigen gehalten oder in kleinen Plastiknäpfchen. Es wurde jeweils die betreffende Tierart mit wachsenden Myzelien zusammen oder mit deren wäßrigem Extrakt oder mit destilliertem Wasser allein gehalten. Dadurch sollte festgestellt werden, ob eine eventuelle Unverträglichkeit beider Partner auf chemische Wirkungen (Extraktversuche) oder auf Nahrungsmangel (infolge der Untähigkeit des Tieres die Myzelien oder Sporen zu fressen) beruht. Alle Arten von Aktivität, wie Nahrungsaufnahme, Bewegung, Kotabgabe und Fortpflanzung, wurden regelmäßig beobachtet. Außerdem wurden jeweils der Darminhalt und die Losung mikroskopisch untersucht, um nachzuweisen, ob Pilzmaterial überhaupt aufgenommen und in welchem Umfang es verdaut wird.

Es lassen sich folgende Fälle unterscheiden: Arten, die sich von Myzelien und Sporen ernähren können, wie die Collembolen *Entomobrya lanuginosa* und *Hypogastrura granulata* und die Milben Laelaptidae Gen. sp., *Rhizoglyphus echinopus*, *Hypochthonius rufulus* und *Liacarus tremellae*. Nur an sterilen Myzelien frißt *Achipteria coleoptrata*, während *Isotomiella minor* und *Oppia nitens* anscheinend nur Sporen fressen können. Folgende Arten verhungern eher, bevor sie irgendwelche pilzliche Substanzen fressen: die Collembolen *Folsomia multiseta* und *Sminthurides pumilis* sowie

Arrhopalites cochlearifer und die Milben *Prozercon fimbriatus*, *Oppia splendens*, *O. ornata*, *Rhagidia ardua* und *Tropacarus pulcherrimus*.

Die geschilderte Nahrungsspezialisation gilt natürlich nur gegenüber den beiden genannten Schimmelpilzen; schon gegenüber Sporen höherer Pilze (Basidiomyceten) verhalten sich z. B. Hypogastrura-Arten anders, indem sie unverletzte Sporen nicht verdauen können.

Die Bedeutung der Pilzflora eines Bodens für seine Kleinarthropodenfauna wird diskutiert.

8. Literature

AGRELL, I., 1941. Zur Ökologie der Collembolen. Opuscula Entomologica, Suppl. **3**, 236.

BAKER, E. W., and WHARTON, G. W., 1959. An introduction to Acarology. Macmillan Company, New York.

DRIFT, J. VAN DER, 1951. Analysis of the animal community in a beech forest floor. Meded. Inst. Tolgep. Biol. Onderz. Natuur. **9**, 1—165.

FENTON, G. R., 1947. The soil fauna: with special reference to the ecosystem of forest soils. J. Anim. Ecol., **16**, 76—93.

FORSSLUND, K. H., 1938. Über die Ernährungsverhältnisse der Hornmilben (Oribatiden) und ihre Bedeutung für die Prozesse im Waldboden. Verh. VII. Intern. Kongr. Ent., Berlin, 3, 1950 bis 1951.

— 1943. Studien über die Tierwelt des nordschwedischen Waldbodens. Meddel. från Statens Skogsförsoksanstalt, 34, 283.

FRENZEL, G., 1936. Untersuchungen über die Tierwelt des Wiesenbodens. Jena.

GISIN, H., 1943. Ökologie und Lebensgemeinschaft der Collembolen im Schweizerischen Exkursionsgebiet. Revue Suisse de Zoologie, **50**, Nr. 4.

— 1960. Collembolenfauna Europas. Museum d'Histoire Naturelle, Genève.

HANSCHIN, E., 1926. Collembola, Springschwänze. P. Schultzte: Biologie der Tiere Deutschlands. Teil 25.

HARTENSTEIN, R., 1962. Soil Oribatei. I. Feeding specificity among forest soil oribatids. Ann. Entomol. Soc. Am., **55**, 202—205.

KÜHNELT, W., 1950. Bodenbiologie. Herold. Wien.

— 1961. Soil Biology. Faber and Faber, London.

— 1963. Über den Einfluß des Mycels von *Clitocybe infundibuliformis* auf die Streufauna. In: DOEKSEN, J., and J. VAN DER DRIFT (ed.). Soils Organisms. Amsterdam 281—288.

MACNAMARA, C., 1924. The food of Collembola. Canad. Entomologist. **56**, 99—104.

MURPHY, P. W., 1953. The biology of the forest soils with special reference to mesofauna. J. Soil. Sci., **4**, 155—193.

RIHA, G., 1951. Zur Ökologie der Oribatiden in Kalksteinböden. Zool. Jb. Syst., **80**, 407—450.

SCHALLER, F., 1950. Biologische Beobachtungen an humusbildenden Bodentieren insbesondere an Collembolen. Zool. Jb. Syst., **78**, 506—525.

SCHUSTER, R., 1956. Der Anteil der Oribatiden an den Zersetzungsvorgängen im Boden. Z. Morph. u. Ökol. Tiere, **45**, 1—33.

WEIS-FOGH, T., 1948. Ecological investigations on mites and collemboles in the soil. Natura Jutlandica, **1**, 139—270.

WOODRING, J. P., 1963. The nutrition and biology of saprophytic Sarcoptiformes. Advances in Acarology, **1**, 89—111.

Address of the author: Dr. A. Z. FARAHAT, Zoology Department, Assiut University, U. A. R.

Table 3. Survival (expressed in days) of isolated cultures of Collembola and Acari under various experimental conditions.

	Experiments	Adults in gypsum cages with fungi					Nymphs in gypsum cages with fungi					Adults in plastic trays with fungi				
	Name	No. exp.	No. indiv.	Min. life	Max. life	Aver. life	No. exp.	No. indiv.	Min. life	Max. life	Aver. life	No. exp.	No. indiv.	Min. life	Max. life	Aver. life
Collembola	*Entomobrya lanuginosa*	6	62	60	60	60	5	70	30	30	30	2	20	60	60	60
	Hypogastrura granulata	.	.	.	.	.	.	.	.	.	.	5	52	20	46	33
	Isotomiella minor	12	63	3	35	19	2	20	3	37	20	8	141	2	30	16
	Folsomia multiseta	10	62	2	4	3	.	.	.	.	.	6	70	2	4	3
	Sminthurides pumilis	5	14	2	3	2.5	.	.	.	.	.	4	24	3	5	4
Mesostigmata	Gamasina (big species)	5	36	34	60	47	4	12	30	3	30	4	73	6	30	18
	Gamasina (small species)	3	44	60	60	60	2	20	30	30	30	2	20	60	60	60
	Uropodina	5	11	60	60	60	.	.	.	.	.	2	7	60	60	60
	Prozercon fimbriatus	5	45	6	30	18	.	.	.	.	.	8	70	3	7	5
Cryptostigmata	*Rhizoglyphus echinopus*	9	100	60	60	60	10	80	30	30	30	4	53	60	60	60
	Oppia nitens	.	.	.	.	.	.	.	.	.	.	2	30	20	40	30
	Oppia splendens	4	16	3	10	65	.	.	.	.	.	3	28	2	5	35
	Rhysotrilia ardua	3	12	18	34	26	.	.	.	.	.	4	31	6	22	14
	Achipteria coleoptrata	2	7	36	60	48	.	.	.	.	.	3	13	2	4	3
	Hypochthonius rufulus	2	16	30	30	30	.	.	.	.	.	2	10	30	30	30
	Liacarus tremellae	.	.	.	.	.	.	.	.	.	.	1	4	90	90	90

Adults in plastic trays without food					Adults in plastic trays with fungal extract					Adults in plastic trays with distilled water					Gut contents		Moulting
No. exp.	No. indiv.	Min. life	Max. life	Aver. life	No. exp.	No. indiv.	Min. life	Max. life	Aver. life	No. exp.	No. indiv.	Min. life	Max. life	Aver. life	Hyphae	Spores	
3	32	12	26	19	2	26	60	60	60	2	20	2	4	3	+	+	—
2	14	11	17	114	2	16	4	12	8	1	8	16	30	23	+	+	—
5	34	3	5	4	2	68	2	3	25	3	12	2	4	3	+	—	—
4	32	1	4	3	4	20	1	3	2	6	28	2	4	3	—	—	—
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	—	—	—
4	18	8	20	14	3	25	0,5	1,5	1	3	14	5	11	8	+	—	—
2	8	16	18	17	2	13	0,5	1,5	1	2	8	5	12	85	+	+	—
2	4	10	20	15	2	6	20	22	21	2	8	12	22	17	+	—	—
3	26	2	8	5	2	27	2	4	3	2	12	2	11	6,5	+	—	—
2	14	10	24	17	2	21	30	30	30	2	19	8	20	14	+	+	+
2	10	3	5	4	.	.	.	.	.	1	6	2	4	3	—	+	—
2	13	4	6	5	3	27	1	2	1.5	3	18	3	9	6	—	—	—
3	23	6	16	17	2	12	16	18	17	2	12	17	22	18.5	—	—	—
2	8	4	17	105	1	12	15	15	15	2	8	10	20	15	+	—	—
1	3	4	4	4	1	10	0,5	15	1	1	8	4	6	5	+	+	—
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	—